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(54) Method of and Apparatus for Mixing Substances

(57) In the mixing of substances agitating means is reciprocated through the material by mechanical impacts produced through impulses from electro-magnetic means. In the embodiment described a reservoir 1, has a mixing means 6, and means for producing reciprocating movement of the mixing means 6 in the form of eddy current electromagnetic inductors 13 at each end connected to a current source 14. A storage capacitor 19 and a turn-on sequencer 15 are provided for the electromagnetic inductors 13, and elements 16 are made of an electrically conductive material. Additional electromagnetic conductors 22 may be provided spaced longitudinally along the side of the reservoir whereby transverse impulses may be applied to the materials to further improve mixing.

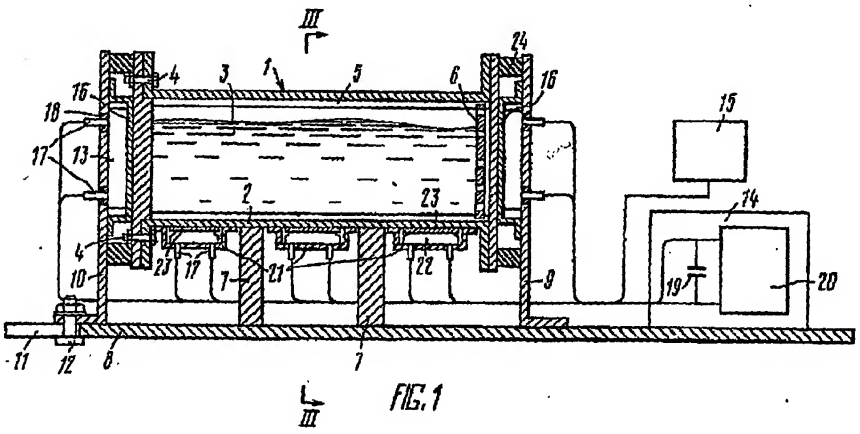

FIG. 1

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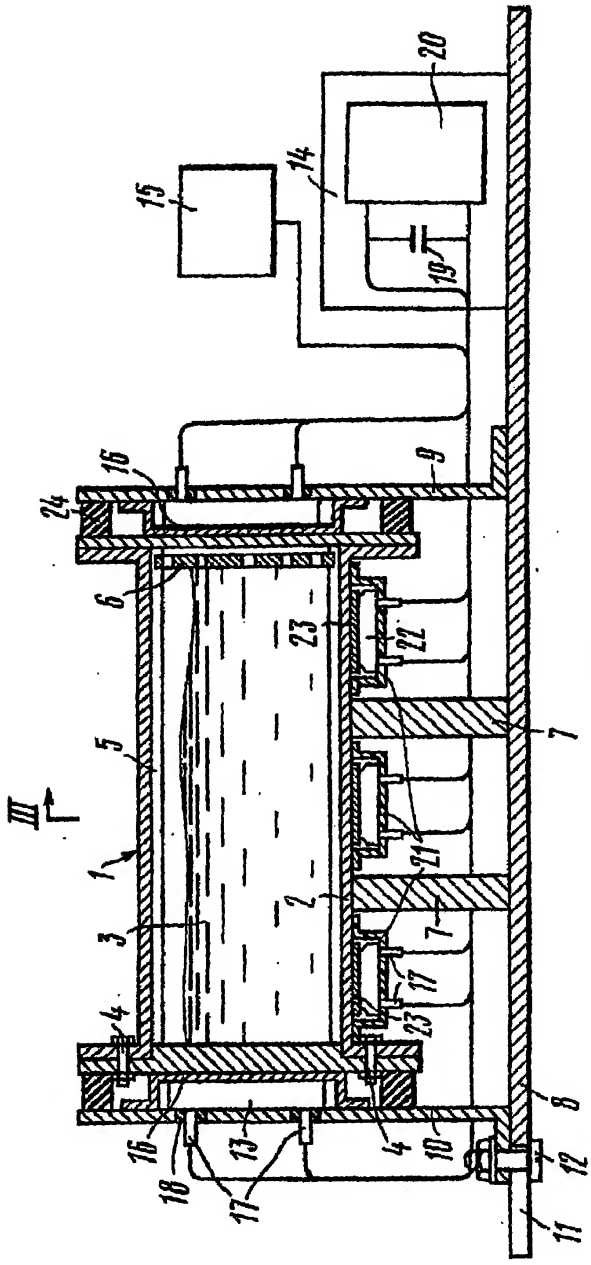

FIG. 1

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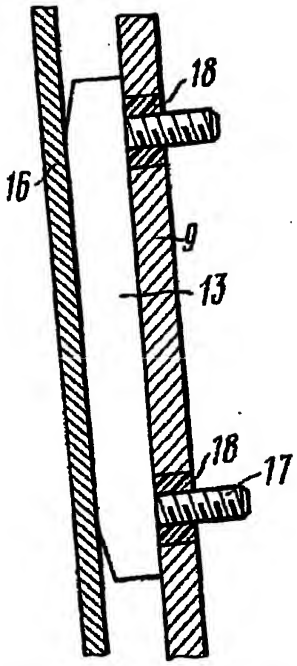

FIG. 2

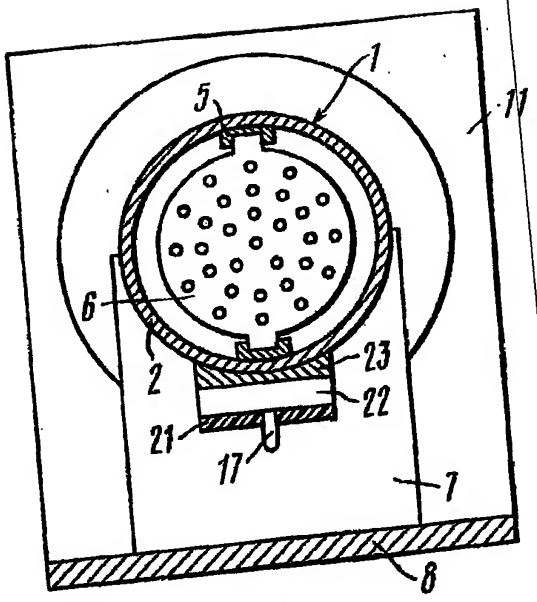

FIG. 3

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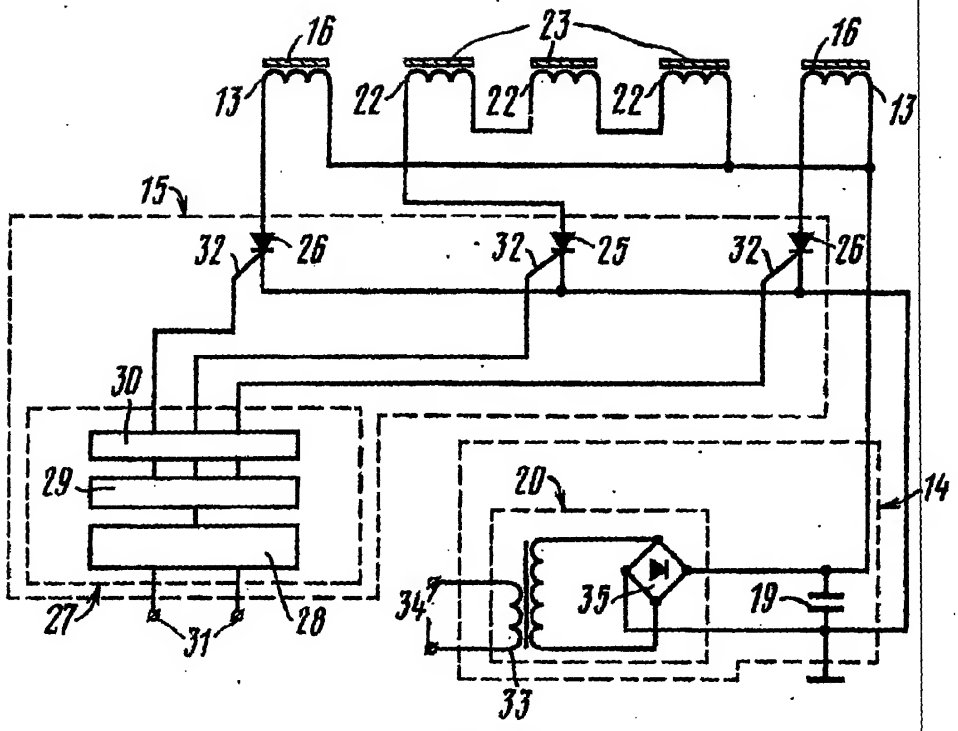

FIG. 4

SPECIFICATION

Method of and Apparatus for Mixing Substances

The invention relates to general-purpose methods of and apparatuses for various physical and chemical processes, and more particularly to methods of and apparatuses for mixing substances.

Such method and apparatus are applicable to the mixing of liquid mixtures, suspensions, loose materials, gas-liquid systems and the like and can find use, therefore, in chemical, food, pharmaceutical and other industries.

According to one aspect of the invention, there is provided a method of mixing substances which are subjected to reciprocating movement, comprising generating mechanical impulses to effect said reciprocating movement.

Advantageously, mechanical impulses at right angles to the reciprocating movement of the substances being mixed are generated.

Preferably, the mechanical impulses at right angles to the reciprocating movement of the substances being mixed are generated simultaneously with respective mechanical impulses for providing the reciprocating movement of the substances being mixed.

Advantageously, the mechanical impulses at right angles to the reciprocating movement of the substances being mixed are generated during periods between the mechanical impulses for providing the reciprocating movement of the substances being mixed.

Preferably, the mechanical impulses providing for the reciprocating movement of the substances being mixed and the mechanical impulses at right angles to the reciprocating movement of the substances being mixed are generated according to a predetermined sequence.

Preferably, the mechanical pulses have a duration ranging from 10^{-6} to 10^{-2} seconds, the ratio between the spacing of the mechanical impulses and their duration being in a range of 10 to 10,000.

According to another aspect of the invention, there is provided an apparatus for mixing substances according to the method of the invention, comprising a reservoir accommodating a mixing means, and means for producing reciprocating movement of the mixing means, the reciprocating movement producing means including a respective eddy current electromagnetic inductor disposed in immediate proximity to each end wall of the reservoir and connected in a current surce having a storage capacitor, a turn-on sequencer for the electromagnetic inductors, and elements made of an electrically conductive material and arranged in contact with the electromagnetic inductors.

Preferably, the turn-on sequencer for the eddy current electro-magnetic inductors comprises two or more thyristors whose gas electrodes are connected to a program switch.

Advantageously, the elements made of an electrically conductive material are disposed between their respective eddy current electromagnetic inductors and corresponding end walls of the reservoir.

Preferably, the end walls of the reservoir constitute respective elements made of an electrically conductive material.

Advantageously, a side wall of the reservoir mounts further eddy current electromagnetic inductors which are connected in series to the current source having the storage capacitor, and further elements made of an electrically conductive material are disposed between the side wall and the further electromagnetic inductors.

The method and apparatus of the invention make it possible to increase the efficiency of the process of mixing substances.

The power taken from an external power source is considerably reduced since the storage capacitor stores the electric energy during the spacings between the mechanical impulses.

The power N_1 provided by a mechanical impulse is determined by

$$N_1 = N_2 \cdot (t+T)/t \qquad (1)$$

where

N_2 is the power provided by an external power source;

η is the efficiency of the apparatus;

t is the duration of a mechanical impulse;

T is the spacing of the mechanical impulses,

where preferably

$$10 \frac{T}{t} 10{,}000.$$

With $t=1.\ 10^{-3}$s, T=1 s, and η=90%, the value of N_2 is 800 times lower than the value of N_1.

The invention will now be described in more detail, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a general view of an apparatus for mixing substances constituting a preferred embodiment of the invention;

Figure 2 is an element made of an electrically conductive material;

Figure 3 is a section taken along the line III—III of Figure 1, illustrating mixing means mounted on guide members;

Figure 4 is a circuit diagram illustrating the connection of eddy current electromagnetic inductors.

A method of mixing substances comprises subjecting the substances to reciprocating movement, which is attained by generating mechanical impulses providing for a higher effectiv ness of the mixing operation. According to the method, a furth r incr ase in the ffectiveness of the mixing operation may be attained by applying to th substances being mixed mechanical impulses which are at right angles to the reciprocating movement of the

substances. Concurrent generation of the mechanical impulses responsible for the reciprocating movement of the substances being mixed and the mechanical impulses that are at right angles to the reciprocating movement makes it possible to reduce the time required for the mixing operation in the case when the substance viscosity and the apparatus dimensions allow for effective distribution of the energy consumed in generating the mechanical impulses.

It is possible to generate the mechanical impulses that are at right angles to the reciprocating movement of the substances being mixed during the spacings between the mechanical impulses providing for the reciprocating movement, or to generate the two types of mechanical impulses according to a given sequence.

In the second case, an increase in the time required for the mixing operation takes place, but the two types of mechanical impulses may have greater power, which allows for the mixing of more viscous substances in apparatuses of a greater capacity, as compared to the case of concurrent generation of the impulses.

The above-mentioned mechanical impulses have a duration ranging from 10^{-5} to 10^{-2}s (seconds), thereby ensuring various operating modes for effective mixing of the substances, the amplitude of a mechanical impulse being inversely related to its duration.

Mechanical impulses of duration exceeding 10^{-2}s results in a considerable decrease in the effectiveness of the mixing operation.

Mechanical impulses of duration less than 10^{-5}s requires an apparatus which is difficult to develop and utilize. An optimum ratio of the spacing of mechanical impulses to their duration is in a range from 10 to 10,000, which provides for effective mixing of the substances and for a reduced amount of power taken from an external power source.

Increasing the above-mentioned ratio above 10,000 results in too large a time interval for the mixing operation; on the other hand, a decrease of that ratio below 10 requires more power since a storage capacitor must be charged to a rated value for a short time interval.

Given below are Examples illustrating embodiments of the invention.

Example 1

A preferred method according to the invention is used to mix liquid mixtures including motor oil and liquid admixture, which serves to decrease the solidification temperature of the oil. The above-mentioned components are introduced into the reservoir of the apparatus according to the following percent ratio: 99 percent of motor oil and 1 percent of calcium alkylphenolate.

These substances are mixed by subjecting them to reciprocating movement provided by mechanical impuls s along with concurrent generation of mechanical impulses that are at right angles to the first-mentioned mechanical impulses.

The mechanical impulses have a duration of 10^{-3}s and a spacing of 1 s. The electric power being accumulated is distributed in a manner such that these mechanical impulses are generated.

The characteristics of the mixing operation are as follows:

time required for mixing, 25 s;

power taken from an external power source, 500 W; and

energy consumed during the mixing operation, 4 W—h.

The preferred method provides for an increased efficiency of the mixing operation, for a decreased mixing time, and for a reduced power taken from an external power source.

Example 2

A preferred method according to the invention is used to mix loose substances with the result that a moulding mixture is provided. The following components, according to a percent relation, are introduced into the apparatus reservoir;

quartz sand, 60 percent; used mixture, 35 percent; clay 3 percent; binding substance, which is an argillo-sulphide emulsion of peat pitch, 2 percent.

The substances are mixed by subjecting them to a reciprocating movement provided by mechanical impulses and further mechanical impulses, which are at right angles to the first-mentioned mechanical impulses, are generated, the two types of mechanical impulses being generated according to a given sequence. To generate a mechanical impulse belonging to the two above-mentioned types, the entire accumulated energy is consumed, with the result, that the mechanical pulses produced have a greater intensity as compared to those of the previous example.

The characteristics of the mixing operation are as follows:

duration of mechanical impulses, 10^{-2}s;

spacing of mechanical impulses, 2s;

mixing time, 60s;

power taken from external power source, 2.5 KW;

energy consumed during mixing operation, 45 W—h.

This preferred method provides, in this case, for an increased efficiency of the mixing operation, for a decreased mixing time, and for a reduced power taken from an external power source.

A preferred apparatus comprises a reservoir 1 (Figure 2) having a side wall 2 and end walls. One of the end walls is rigidly fixed to the side wall 2, for example, by welding, and the other end wall constitutes a lid of the reservoir 1. The lid is fixed to the side wall 2 using bolts 4 and substances 3 are charged through the lid into the reservoir 1. The inner side of the side wall 2 rigidly mounts guide members 5 which accommodate a mixing

means 6 in the form of a perforated diso. There are cradles 7 which are on the base of a frame 8 and are used to mount the reservoir 1. The frame 8 has two vertical walls, 9, 10, the wall 9 being fixed immovably on the base of the frame 8, for example, by welding, and the wall 10 being allowed to move longitudinally in slots 11 on the base of the frame 8 and being fixed by bolts 12. The apparatus also comprises a reciprocating movement mechanism of the mixing means 6, which mechanism includes eddy current electromagnetic inductors 13 installed in close vicinity to the end walls of the reservoir 1, on respective vertical walls 9, 10, and are coupled to a current source 14 and to a turn-on sequencer 15 for the eddy current electromagnetic inductors 13. The reciprocating movement mechanism also includes elements 16 made of an electrically conductive material and arranged in the form of plates which are disposed between the inductors 13 and end walls of the reservoir 1. The inductors 13 are made in the form of several wire turns housed in a dielectric envelope, and are provided with power lead elements 17 which are also used for mounting the inductors 13 on the walls 9, 10, the walls 9, 10 being used to accommodate dielectric inserts 18.

According to other embodiments of the invention, there may be two or more inductors 13 mounted on the walls 9, 10 which depend on the apparatus characteristics including its dimensions, on the substances being mixed, and on the other parameters.

The current source 14 comprises a storage capacitor 19 and a converter 20. Installed on the outer side of the side wall 2 on dielectric brackets 21 are three eddy current electromagnetic inductors 22 which are analogous to the inductors 13 and are connected in series with each other. According to other embodiments of the invention, any other number of the inductors 22 can be used, depending on the dimensions of the reservoir 1.

The inductors 22 are coupled to the current source 14 and in contact with elements 23 made of an electrically conductive material, which constitute plates disposed between the inductors 22 and the side wall of the reservoir 1. The turn-on sequencer 15 provides for the required sequence of turning-on of the inductors 22.

To increase the output of the inductors 13, 22, the elements 16, 23 must be made of a material offering a higher electric conductivity, for example, of copper or aluminum. There are shock-absorbing gaskets 24 which serve to resist impacts that may occur between the inductors 13 and the walls 9, 10 of the frame 8.

The end wall of the reservoir 1 (Figure 2) can serve as the element 16.

Figure 3 is a section taken along the line III—III of Figure 1, illustrating the location of the mixing means in the guide members 5. The latter are used to maintain the mixing m ans 6 in parallel with the end walls of the reservoir 1 as it m ves from one end wall to another.

The turn-on sequencer 15 (Figure 4) for th inductors 13, 22 comprises thyristors 25, 26 and a program switch 27 which includes a serial arrangement of a pulse generator 28, a ring-type shift register 29, and a pulse amplifier 30, the program switch 17 being connected to voltage supply terminals 31, and gate electrodes 32 of the thyristors 25, 26 being coupled to the program switch 27. The inductors 13, 22 are coupled to the current source 14 in the following manner. The group including three inductors 22, which are connected in series to one another, is connected to the current source 14 *via* the thyristor 25, while the inductors 13 are coupled to the current source 14 through their respective thyristors 26.

The current source 14 comprises a storage capacitor 19 and a converter 20 which includes a step-up transformer 33, having its primary winding connected to voltage supply terminals 34, and a rectifier 35.

The apparatus operates in the following manner. The reservoir 1 (Figure 1), whose side wall 2 mounts the inductors 22, is arranged vertically and the substances 3 being mixed are introduced therein through its end wall which serves as the lid of the reservoir 1. In this case, the mixing means is arranged on the other end wall of the reservoir 1 so that a certain sequence is defined according to which the inductors 13 are turned on. After the substances 3 have been charged, the reservoir 1 is closed tight using the bolts 4 and is installed on the cradles 7 so that its end wall abuts against the shock-absorbing gaskets 24 on the vertical wall 9 of the frame 8. The movable wall 10 of the frame 8 is displaced to be in intimate contact with the end wall of the reservoir 1 so that the shock-absorbing gaskets 24 rest on that end wall, and is then fixed using the bolts 12 to acquire a position in which the elements 16 touch the end walls of the reservoir 1. When it is impossible to provide for close relationship between the elements 16 and the end walls of the reservoir 1, a clearance not exceeding 1.5 mm may be allowed to be therebetween.

The establishment of contact relation (or a minimum clearance) between the elements 16 and the end walls of the reservoir 1 is a critical factor that influences effective operation of the inductors 13. Note that a similar contact should be attained between the side wall 2 of the reservoir 1 and the elements 23 in mounting the brackets 21 on the side wall 2.

The inductors 13, 22 are then connected electrically to the current source 14.

When the supply voltage is applied to the terminals 34 (Figure 4) of the current source 14, the storage capacitor 19 charges *via* the step-up transformer 33 and the rectifier 35. At the same time, the supply voltage is applied to the terminals 31 of the program switch 27.

When a signal from th program switch 27 is applied to the gate lectrodes 32 of any one of the thyristors 25, 26, or applied concurrently to the gate electrodes 32 of the thyristor 25 and on of

the thyristors 26, the respective thyristors are made conducting and the storage capacitor 19 is discharged *via* the inductors 13, 22. The program switch 27 operates to control the turning-on of the inductors 13, 22 according to a given sequence.

The pulse generator 28 provides a continuous train of voltage pulses which are delivered to the ring-type shift register 29 and are then amplified in the pulse amplifier 30.

Prior to operation, a logic 1 is placed in the first bit position of the shift register 29, while the remaining bit positions thereof receive logic 0's. The arrival of the first pulse from the pulse generator 28 makes the thyristors 25, 26, connected to the first bit position of the register 29, conducting, and the logic 1 is transferred to the second bit position; this means that the arrival of the second pulse from the pulse generator 28 causes the thyristors 23, 26 connected to the second bit position of the register 29 to conduct, and the logic 1 is transferred to the next bit position.

Concurrent generation of the mechanical impulses at right angles to the reciprocating movement of the substances being mixed and the mechanical impulses providing the reciprocating movement will now be considered. In this case, the program switch 27 operates to cause the conducting state of the thyristor 25 and one of the thyristors 26, with the result that the storage capacitor 19 is discharged *via* the group of inductors 22 (Figure 1) and *via* one of the inductors 13. The first pulse causes concurrent operation of the inductors 22 and that inductor 13 which is installed near the end wall of the reservoir 1, said end wall being rigidly fixed to the side wall 2 of the reservoir 1. A current pulse passes through the turns of the inductor 13 and produces in the vicinity to the latter an alternating magnetic field pulse, with the result that eddy currents are induced in the element 16. The current passing through the turns of the inductor 13 interacts with the eddy current of the element 16 and the latter is therefore forced vigorously away from the inductor 13 which is rigidly fixed to the wall 9. The kinetic energy of the element 16 is transferred to the end wall of the reservoir 1, which is rigidly attached to the side wall 2 of the reservoir 1, and the end wall is subjected to elastic deformation. As a result, a contactless impact takes place on the end wall of the reservoir 1. Since the mixing means 6 is in contact with the interior of the end wall of the reservoir 1 at that point in time, the end wall transfers the mechanical impulse so created to the mixing means 6 and the latter therefore moves with a greater speed towards the other end wall of the reservoir 1 and drives in the course of its movement a portion of the substances 3 being mixed. The other portion of the substances 3 passes through the holes in the mixing means 6 and is displaced towards the rigidly attached end wall. The speed of the mixing means 6 reaches 30 m/s. Thus, the contactless mechanical impulse makes it possible to avoid a rigid coupling between the mixing means 6 and a driver, for example a pneumatic or electromagnetic one, installed outside of the reservoir 1, which coupling, if any, would reduce the effectiveness of transfer of the mechanical impulse since a considerable amount of the kinetic energy of the mixing means 6 would be consumed by that coupling.

The apparatus is also advantageous in that there is no device which provides for the introduction of that rigid coupling into the reservoir 1.

As the mixing means 6 moves, it is brought into intimate contact with the interior of that end wall of the reservoir 1 which serves as the lid of the reservoir.

At the moment when the mechanical impulse described above acts on the rigidly attached end wall, the inductors 21, analogous to the inductors 13, operate to act on the side wall 2 of the reservoir 1, with the result that the side wall 2 is subject to elastic deformation. The compression waves tend to propagate from the deformed locations into the bulk of the substances 3 being mixed, with the result that the latter are thrown up. As a result, the reciprocating movement of the substances 3 from one end wall to another and vice versa is accompanied by the movement of the substances 3 along a direction at right angles to the direction of the reciprocating movement, thereby providing for more effective mixing of the substances.

The first impulse is followed by a period within which the storage capacitor 19 stores the electric energy to be consumed during the next impulse. The storage capacitor 19 provides the power for the mechanical impulse which is tens to hundreds of times as much as the power taken from an external power source, resulting in an increased operational effectiveness of the apparatus and allowing for a decrease in the power requirements.

After the period has elapsed, the program switch 27 (Figure 4) causes concurrently the conduction of the thyristor 25 and the thyristor 26 which is coupled to the inductor 13 mounted near that end wall which serves as the lid of the reservoir 1. A process analogous to that described above therefore takes place and the mixing means 6 under the action of a mechanical impulse produced by the inductor 13 is moved towards the other end wall, thereby mixing the substances 3. At the same time, the substances 3 are thrown up under the action of another mechanical impulse provided by the inductors 22 and applied to the side wall 2 of the reservoir 1.

After that, a space period is provided and the operation cycle is repeated.

As stated above, the mechanical impulses at right angles to the reciprocating movement of the substance 3 may be generated during the spacings between those mechanical impulses which provide for the reciprocating movement. In this mode of operation, the turn-on sequencer 15

is operated to serially activate th inductor 13 on the vertical wall 9 of the frame 8, the group of the inductors 22 on the side wall 2, and the inductor 13 on the vertical wall 10 of the frame 8. The operation cycle is terminated at the moment when the group of the inductors 22 on the side wall 2 is activated again.

The turning-on of each of the inductors 13 and of the group of the inductors 22 is followed by a period during which the energy for the next mechanical impulse is stored.

In the case of the operating mode providing sequential generation of the mechanical impulse providing for the reciprocating movement of the substances and of the mechanical impulses at right angles to the reciprocating movement, the turn-on sequencer 15 turns on serially the inductor 13 on the vertical wall 10 of the frame 8 and the group of the inductors 22 on the side wall 2 of the reservoir 1. The activation of the inductors 13, 22 results in the occurrence of the processes described above.

After each of the inductors 13 and the group of the inductors 22 has been turned off, a period is provided during which the energy for the next pulse is stored.

The apparatus operates in a pulsed mode. The duration of a mechanical impulse is determined by the time interval for which the currents within the turns of the inductors 13, 22 are present and interact with the current induced in th elements 16, 23. The above-mentioned duration can be adjusted by varying the charge time of the storage capacitor 19 and determines the amplitude of the mechanical impulse. That amplitude must be of a value sufficient for the mixing means 6 to move rapidly to the opposite end wall of the reservoir 1 and for the substances 3 to be thrown up when the side wall 2 of the reservoir 1 is influenced by the inductors 22; note that in this case the stresses occurring within the walls of the reservoir 1 should not exceed the value of the cyclic strength of the material. This means that the duration of a mechanical impulse must amount to 0.001—0.25 of the period of the inherent oscillations of the construction. Advanced constructions offer a stiffness at which the frequency of the inherent oscillations is at a level of not less than 30 Hz.

With the preferred apparatus and method, effective mixing of substances may be achieved, with the result that higher labour productivity can be attained along with a considerable reduction of the power taken from an external power source.

Claims

1. A method of mixing substances which are subjected to reciprocating movement, comprising generating mechanical impulses to effect said reciprocating mov ment.

2. A method as claim d in claim 1, further comprising subjecting the substances being mixed to mechanical impul es which are at right angles to the reciprocating movement of the substances.

3. A method as claimed in claim 2, further comprising g nerating the mechanical impulses at right angles to the reciprocating movement of the substances being mixed simultane usly with respective mechanical impulses for providing the reciprocating movement of the substances being mixed.

4. A method as claimed in claim 2, further comprising generating the mechanical impulses at right angles to the reciprocating movement of the substances being mixed during periods between the mechanical impulses for providing the reciprocating movement of the substances being mixed.

5. A method as claimed in claim 2, further comprising generating in a predetermined sequence the mechanical impulses for providing the reciprocating movement of the substances being mixed and the mechanical impulses at right angles to the reciprocating movement of the substances being mixed.

6. A method as claimed in any one of claims 1 to 5, in which the mechanical impulses have a duration ranging from 10^{-6} to 10^{-2} seconds, the ratio between the spacing of the mechanical impulses and their duration being a range of 10 to 10,000.

7. An apparatus for mixing substances according to a method as claimed in claim 1, comprising a reservoir accommodating a mixing means, and means for producing reciprocating movement of the mixing means, the reciprocating movement producing means including a respective eddy current electromagnetic inductor disposed in immediate proximity to each end wall of the reservoir and connected to a current source having a storage capacitor, a turn-on sequencer for the electromagnetic inductors, and elements made of an electrically conductive material and arranged in contact with the electromagnetic inductors.

8. An apparatus as claimed in claim 7, wherein the turn-on sequencer comprises thyristors whose gate electrodes are connected to a program switch.

9. An apparatus as claimed in claim 7 or 8, wherein the elements made of an electrically conductive material are disposed between the respective electromechanical inductors and corresponding end walls of the reservoir.

10. An apparatus as claimed in claim 7 or 8, wherein the end walls of the reservoir constitute the respective elements made of an electrically conductive material.

11. An apparatus as claimed in any one of claims 7 to 10, wherein a side wall of the reservoir mounts further eddy currents electromagnetic inductors which are connected in series to the current source having the storage capacitor, further elements made of an electrically conductive material being disposed between the side wall of the reservoir and the further electromagn tic inductors.

12. A method of mixing substances according to ither of the Exampl s described h reinbefore.

13. A method of mixing substances,

substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

14. An apparatus for mixing substances, substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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